DOE Research and Technology Against the Threat of Weapons of Mass Destruction

Review of the Department of Energy Office of Nonproliferation Research and Engineering (NN-20)

Department of Energy
Nonproliferation and National Security
Advisory Committee

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Membership of the Department of Energy Nonproliferation and National Security Advisory Committee

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Assistant Secretary for Nonproliferation and National Security Rose Gottemoeller, who requested this review, set the tone by encouraging the Committee to look wherever it felt was necessary to carry out its work.

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Executive Summary

Origin of this Report

The Nonproliferation and National Security Advisory Committee (NNAC) was established in August 1999 at the request of the Secretary of Energy. The Advisory Committee reports to the Assistant Secretary for Nonproliferation and National Security (NN-1). The role of the committee is to advise the Department of Energy (DOE) on all aspects of its research and technology development programs for nonproliferation, arms control, and national security and the linkages of such technologies to national security policy (Appendix A).

The first charge to the NNAC was to review the R&D portfolio of the Office of Nonproliferation Research and Engineering, NN-20 (Appendix B). This report presents the findings and recommendations of the Advisory Committee.

Conclusions and Recommendations

The research portfolio of NN-20 supports broad national policies defined by the Executive Branch and Congress and by the need to capitalize on and sustain a robust nonproliferation and national security technology base that is forward looking.

The Office of Nonproliferation and National Security (NN) of the Department of Energy has responsibility for technology and policy development in support of national goals for nonproliferation of weapons of mass destruction and treaty verification. In the area of nuclear nonproliferation, DOE's Office of Nonproliferation Research and Engineering (NN-20) is the predominant sponsor of research and development of new technologies relevant to the nonproliferation mission that supports the national security community. This mandate reaches back to the Atomic Energy Commission. As part of a coordinated national plan, NN-20 has more recently been given the additional responsibility for developing technologies that support domestic U.S. chemical and biological counterterrorism goals.

Administration of the Office of Nonproliferation Research and Engineering (NN-20) requires attention to a wide spectrum of technologies and applications. The office supports directed-basic research, applied research, engineering development, prototype manufacture, and, in a few cases, manufacture of operational devices. NN-20 must respond on short notice to calls for support for international negotiations or agreements and at the same time must also anticipate future needs that are often not well defined. Finally, because NN-20 does not itself operate systems, it faces two difficult challenges: (i) it must transfer the technologies it develops to end-users elsewhere in government, primarily the Defense Department, the intelligence community, and law enforcement, and (ii) it must insure that the policy community is well-informed of the potential and limitations of technology.

The Administration of the NN-20 Office has performed well in recent years in carrying out its responsibilities across a widening spectrum of technology requirements and national policy needs, in spite of the fact its resources have not grown commensurately with its assigned responsibilities.

Significant improvements in the administration and execution of NN-20 operations have taken place since a review of the Office was conducted in spring of 1996 by an ad hoc external group. Nevertheless, the Advisory Committee feels there are additional changes in management practice at both the NN and the NN-20 levels that would further improve performance and quality. Implementation of the recommendations presented below would give other elements of the U.S. Government and the national scientific and technical community a greater understanding of and appreciation for NN-20's role and accomplishments.

NN should more fully integrate technology development and policy formulation and analysis in order to fulfill its role as the leading technical arm of the interagency nonproliferation policy community.

NN has the unique responsibility for bringing the scientific and engineering expertise of the DOE national laboratories to bear on the development of U.S. nonproliferation policy as well as to guide research at the laboratories in support of future policy requirements. To achieve better integration of technology and policy, the Advisory Committee urges that the following three recommendations be implemented.

Recommendation 1: Cooperative interactions between the technology and policy offices of NN should become a regular feature of the annual budget and planning process.

At an appropriate time in the budget cycle, NN policy offices should formally cite their nonproliferation technology needs to NN-20, and NN-20 should respond with its plans to address those needs. At other times of the budget year and in a more informal manner, NN-20 together with representatives from the DOE national laboratories should provide NN policy offices with information about new opportunities emerging from technological advances. The policy offices should in turn present their technology implementation plans and practices.

Recommendation 2: NN should assume the responsibility for communicating to the interagency policy community two categories of technical information: (i) the basic capabilities and limitations of today's technologies that support U.S. nonproliferation, arms control, and security objectives, and (ii) the mid- and long-term prospects for improved technologies relevant to the NN mission. This information, which we shall refer to as the Annual Nonproliferation Technology Assessment, should be made widely available within government in the form of a classified annual report or an equivalent communiqué.

Given its history and unique combination of technology and policy expertise, NN has an affirmative responsibility to keep the wider governmental community apprised of the potential--and the limitations--for technology to address national needs. No other unit of the U.S. Government is capable of doing so.

The Annual Nonproliferation Technology Assessment would primarily serve members of interagency groups engaged in developing options for nonproliferation policies and in preparatory work for arms control planning and negotiations and in supporting domestic counterterrorism objectives. However, the Assessment would also strengthen communications among DOE national laboratories and DOE headquarters and provide discipline among proponents of particular technologies by recognizing both the promise and limitations of a given approach.

Recommendation 3: The Advisory Committee recommends that the activities of the DOE Nuclear Transfer and Supplier Policy Division (NN-43) in promulgating lists of unclassified but export-controlled items be subject to review by representatives from the scientific community within NN. In case of conflict, the assistance of the NN Science Advisor should either settle the matter or refer it to higher authority in DOE.

The implementation of export controls on information (knowledge) is an area in great need of help from the technical community. NN has the responsibility, exercised through the NN-43 office, to publish lists of "sensitive unclassified technical information" and export-controlled information.

The breadth of the scientific and engineering work sponsored by NN-20 does not permit a common set of project selection and review procedures to be applied uniformly across its entire R&D portfolio.

Nevertheless, there are principles that can be applied across the portfolio and serve as guidelines to strengthen the selection and review processes and to ensure high quality. Such principles would serve as a unifying influence for choosing appropriate project selection and review procedures for each area of the NN-20 R&D portfolio.

Recommendation 4: NN-20 should expand its use of external merit reviews in project selection decisions and subsequent progress reviews, including it wherever feasible in managing its R&D portfolio.

Merit review is defined by two principal criteria: (1) scientific and technical quality, and (2) potential contribution to nonproliferation and national security goals. The extent to which merit review can be incorporated varies by program area. The chemical and biological nonproliferation program area of NN-20 has made commendable use of merit review for final project selection and some other program areas use it as well but in less explicit ways. For activities that are primarily applied, especially those serving highly classified applications, project selection and review procedures may need to be less open and inclusive, but they should always include individuals from outside of NN-20 and outside of the DOE laboratory community. Where special circumstances make this impractical, the reasons should be documented.

Recommendation 5: The transparency and documentation of the project selection and review processes for the NN-20 R&D portfolio need to be enhanced.

The NN-20 office should ensure that its selection and review procedures are well publicized and well documented. Regular procedures will ensure that the broader science and technology community is informed about the NN-20 program and its purpose and standards.

Recommendation 6: A clear balance needs to be established between the reviews that NN-20 program management conducts to fulfill its responsibilities and what is best done at the laboratory level.

DOE headquarters and the DOE national laboratories can and should have separate domains of accountability. Recommendations 4-5 above are intended as guidelines for all reviews and procedures, not as additional layers of review and management.

DOE Headquarters should focus its attention on initial project selection, end-user needs, integration of technology and policy, and interagency education. Headquarters should rely more on the science and engineering review processes at the laboratories than it currently does for making judgments about the technical progress of projects once they are underway, provided these reviews are done in a manner that is clearly articulated and include technical experts from outside the laboratory. For multi-laboratory projects or when significant technical or budgetary problems arise in previously approved projects at a single laboratory, a combination of headquarters and laboratory reviews would be appropriate. Annual reviews of all projects by NN-20 should continue; redundant reviews should be avoided.

Recommendation 7: Existing practices for NN-20 interactions with end-users need to be given greater visibility and articulation within NN and also in the wider interagency community.

Areas already exist where NN-20 has excellent communications with end-users and representatives from the end-user community are involved in review of programs and technical progress. By expanding and codifying practices within NN-20 that are most effective, relationships with end-users will become more fruitful. This is especially true when NN-20's work is closely tied to end-user needs. There can be unexpected benefits as well. Brainstorming with potential end-uses can sometimes lead to innovative ideas for new technologies.

Recommendation 8: To maximize the prospects for successful transfer of new technologies, communications with potential end-users should be opened as early as possible and proceed through all the phases of the work for which NN-20 has responsibility.

Discussions should be technical, but with the policy implications and costs spelled out with due regard given to the end-user's ability to make commitments to a technology in the development stage. It is important in the earliest phases of concept formulation that a prospective end-user be made aware of technological and scientific advances potentially available from an NN-20 project and that the uncertainties in those assessments be communicated as well. The Annual Nonproliferation Technology Assessment recommended above will help, but direct communications between NN-20 and end-users are needed as well.

There should be greater opportunity for the wider U.S. scientific and technical community to contribute to the success of the NN-20 portfolio. This can be done through open competition administered by DOE Headquarters and through partnerships chosen and managed by the DOE national laboratories.

The DOE national laboratories have a strong history of interaction with the larger scientific and technical community. Participation of non-DOE personnel in NN-20 projects has been successful. The participation of appropriate institutions outside of the DOE national laboratories draws into the NN-20 portfolio the expertise of the broader U.S. scientific and technical enterprise.

Recommendation 9: Program areas of the NN-20 portfolio that are chosen for open competition should be ones in which high expertise already exists in the academic sector and/or the industrial sector.

The NN-20 budget is too small to fund development of expertise in nonproliferation or verification technologies where it does not already exist. Furthermore, it would be wasteful to duplicate expertise that already exists at the DOE national laboratories. For academic competitors the work will need be restricted to the unclassified level or special arrangements made.

Areas that come to mind as candidates for open competition include seismic verification technologies for very low yield underground nuclear tests and chemical and biological agent detection and identification technologies. Other possible areas might be specialized electronic chip development and certain radio-frequency technologies. Many parts of the NN-20 R&D program are unsuitable for competition that reaches beyond the DOE national laboratories.

Recommendation 10: NN-20 should document more systematically funding that goes directly to institutions outside of the DOE system as well as funding that goes to the DOE national laboratories and then goes out to consultants, subcontractors and collaborators.

Partnerships in the form of consultantships, subcontracting, sabbatical visits, etc., involving academic researchers and subcontracting with industry for development and manufacture are all mechanisms with which the DOE national laboratories have much experience. These are clear evidence that the DOE national laboratories reach out to the broader science and technology community when the needed expertise is not available in-house. The recommended documentation will give greater visibility and clarity to existing practices.

The DOE national laboratories were created as partners to the U.S. Government under contracts documenting that partnership, not as contractors in the ordinary sense. Their continued existence requires that they remain centers of excellence and responsive to national needs.

Recommendation 11: NN-20 headquarters and administrators at the DOE laboratory complex who manage funds received from NN-20 should work together to identify metrics that will serve as objective indicators of the quality of the work performed and the impact of that work on nonproliferation and national security goals. Records of quality and impact should be kept and reported on a regular basis.

The diversity of the NN-20 portfolio means that no single set of metrics will be suitable for all areas. Metrics used to evaluate the quality of NN-20 projects and program management should be chosen in a manner matched to the activity being evaluated.

The Committee does not wish to suggest specific metrics. There are many possibilities worth considering. For work at the basic scientific level, publications, invited talks, and research funds received on a competitive basis—the norm in the academic community—can be used for evaluation, but this is suitable for only a small part of the NN-20 R&D portfolio. For applied research and for development activities, metrics that correspond to success in moving projects toward nonproliferation and national security objectives in cost effective ways (and for terminating them when initial expectations prove unjustified!) and for interacting effectively with end-users are needed. Prizes for research and technology achievements, testimonials from end-users of NN-20 technologies, and citations of locations and exercises at which NN-20 technology have been used are possibilities.

Indicators of the quality of individuals funded by NN-20 should be included as well, whether or not the indicators refer directly to NN-20 activities. For example, the selection of an NN-20 supported scientist or engineer for service on an interagency group, receipt of an award from a Laboratory Directed Research and Development (LDRD) competition, patents granted, and the like should all be used.

Most DOE national laboratories have one or more external advisory committees. Reports from such committees usually review performance and can be useful sources of information on the quality of personnel, programs, and projects.

Classified work is intrinsically more difficult to evaluate because the peer group is often small, but a good faith effort needs to be made in every case.

The DOE national laboratories collectively constitute a major sector of the nation's science and technology enterprise along with the academic and industrial sectors. The health of the DOE sector is important to all the other sectors.

Each of the sectors of the national science and technology enterprise has unique capabilities and there are areas of complementing, and in some cases intersecting, expertise—a healthy situation. Each sector contributes to the vigor and quality of the overall national enterprise, and each contributes to national security and the well being of the country.

Recommendation 12: Within the constraints imposed by the need to protect classified information, greater efforts should made to increase professional contacts and interactions between scientists and engineers engaged in NN-20 projects at the DOE national laboratories and members of the larger national scientific and engineering communities.

Professional contacts and interactions are essential to maintaining vibrant scientific and technical work. They can be achieved, for example, by means of seminars, conferences, and exchanges of scientists and engineers. Maintaining contact with the outside national scientific and engineering communities will become all the more important as NN-20 moves with NN into the new DOE National Nuclear Security Administration.

There are, of course, areas where security needs preclude any outside interactions, but this requirement should not drive a restrictive policy that is applied to all areas. For example in the chemical and biological disciplines, the unclassified community outside of DOE has vast resources and knowledge that cannot be duplicated by DOE. DOE scientists and engineers must remain connected to this larger community.

The DOE national laboratories comprise a diverse group of scientists and engineers who understand the signatures of the proliferation of weapons of mass destruction, the technologies that can be marshaled to exploit these signatures, and the requirements of the end-users in the national security community. This unique combination of expertise exists only in the classified environment of the DOE national laboratories. We refer to it as the nonproliferation and national security technology base (NN Tech Base).

DOE laboratory administrators, scientists, and engineers have long expressed concern that the NN Tech Base was endangered, but little or no attention has been paid to these concerns. The one-third reduction in the DOE national laboratories' authority to "tax" programs to fund LDRD budgets in the current fiscal year will further diminish the NN Tech Base.

The NN Tech Base in the DOE laboratory complex is shrinking due to recurrent under-funding. Current trends need to be reversed.

The Advisory Committee recognizes that no single agency or office can be the sole guarantor of the NN Tech Base. However, the Office of Nonproliferation Research and Engineering (NN-20) has long been a key shareholder through its support of the development of technology linked to its nonproliferation and national security objectives. The Office must remain a strong supporter.

Recommendation 13: DOE should seek increased funding for NN-20 for the support of advanced concepts research on nonproliferation and national security technologies in future years. This might be done in steps starting at a level of 5% of the NN-20 R&D budget and growing to 10% or more over time.

An NN-20 budget line named "advanced concepts" has been lost in recent years as DOE was required to take on new nonproliferation technology initiatives but was not given corresponding increases in budget. Restoration of advanced concepts funding should be a high priority.

The need for a stable level of funding for advanced concepts is easily understood. Such funding allows scientists and engineers of the NN Tech Base the opportunity to spend a small fraction of their time conceiving and exploring new ideas that may offer fundamentally new and more capable nonproliferation and national security technologies than those currently available or under development—in other words, the opportunity to be creative in an applied context. Funding for advanced concepts is important in its own right, and it will also help attract the best and the brightest of new generations of scientists and engineers to the NN Tech Base.

A portion of NN-20 R&D portfolio must continue to be flexible and go to the DOE national laboratories in support of high-quality, creative research on future nonproliferation and national security technologies.

Advanced concepts research need not necessarily have a definite end-user, but the scientists and engineers involved should be motivated by possible applications for their work. Indeed, it would be counterproductive to national security to require that all work on nonproliferation and national security technologies be driven by the immediate needs of users. Focusing exclusively on immediate needs, as has happened at some federal laboratories, inevitably turns innovative programs, such as those in the NN-20 R&D portfolio that can occasionally make revolutionary advances, into an evolutionary programs that ultimately become stagnant and produce little of real value.

As a general rule, NN-20 does not carry the development of technologies into the manufacturing stage.

The prime exception occurs for satellite-based sensors that are designed to detect nuclear explosions in the atmosphere or in space. Nuclear Detonation Detection System (NDS) packages are deployed as secondary payloads on ballistic missile infrared early warning Defense Support Program (DSP) satellites and on satellites of the Global Positioning System (GPS).

Recommendation 14: DOE/NN should conduct a study assessing the desirability of DOE continuing to be the manufacturer of operational satellite-based Nuclear Detonation Detection System (NDS) packages. The study should involve participation of all stakeholders.

The key question to examine in the study is whether it might be better to follow an alternative model for the manufacturing stage, a model more in line of what NN-20 does in the rest of its R&D portfolio. Namely, NN-20 would carry the development of new-generation NDS packages through the prototype development and testing stages, and then turn the drawings and specifications over to an industrial manufacturer selected on a competitive basis. DOE scientists and engineers would remained involved as consultants to resolve problems that arise in manufacture and help with liaison to the Air Force Project Office that has responsibility for the GPS.

The question should be decided on the basis of what is best for the country and makes the best use of expertise at the DOE national laboratories. It may be that there is no industrial interest or insufficient industrial expertise in the specialized areas involved in manufacturing the NDS packages to change the way that manufacturing is done now.

(Throughout this report, we use the term "DOE national laboratories" to refer to all DOE laboratories that are officially titled national laboratories as well as DOE facilities that have technical expertise directly related to the nonproliferation mission.)

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1: Nonproliferation and the Department of Energy

The U.S. Department of Energy (DOE) plays a major role in the development of policy and technology in support of U.S. Government efforts to combat the proliferation of weapons of mass destruction. The work of DOE supports the Department of State, Department of Defense, Intelligence Community, Department of Justice, and other elements of the national security community. In this section we review the policy dimension of DOE's involvement. Appendices C and D provide additional information.

Making of U.S. Nonproliferation Policy

In accord with the terms of the Constitution, the President and the Executive Branch set the guidelines for all U.S. foreign policy, including nonproliferation policy. Congress influences foreign policy and nonproliferation policy through the legislative process and through its oversight responsibilities, including Senate consent (or lack thereof) to ratify international treaties, appropriations, and at times with explicit directions with respect to specific programs. National security policy initiatives are developed and implemented by the President through a systematic process established by Congress in legislation, beginning with the National Security Act of 1947. Nonproliferation policy for weapons of mass destruction (WMD) is formulated through an on-going process led by the President and implemented by the executive agencies. The National Security Council (NSC)--consisting of the President, Vice President, the Secretaries of State and Defense, with the Director of Central Intelligence as the intelligence advisor and Chairman of the Joint Chiefs of Staff as the military advisor, and other senior government officials whose expertise is required by the President for specific issues--is at the apex of this process. The Secretary of Energy is included when issues involving the responsibilities and capabilities of DOE, such as energy resources, nuclear weapons, and nonproliferation, are under consideration.

Much of the preparatory work of the National Security Council is done in the "Deputies Committee", where the Deputy Secretary of Energy represents the Department. Interagency Working Groups (IWGs), at which U.S. Government agencies are represented at the Assistant Secretary level, prepare detailed positions on issues and make policy decisions where consensus agreement can be reached. Task forces and committees deal with specific elements or issues being considered by the National Security Council and provide technical support to IWGs. Committees and task forces are often chaired or co-chaired by DOE representatives when the subject matter pertains to the Department's areas of expertise and responsibility.

U.S. Nonproliferation Policy Today

The goals of U.S nonproliferation policy are to prevent and reverse the spread of nuclear weapons; safeguard special nuclear weapon materials; eliminate chemical and biological weapons world-wide; prevent the spread of ballistic missiles; and promote effective, verifiable arms control agreements.

Nuclear nonproliferation goals include:

- Eliminate the testing of nuclear weapons to strengthen the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) regime,
- Expand nuclear-weapon-free zones,
- Assist in the prevention of nuclear proliferation from the former Soviet Union,

- Engage China in cooperative efforts to curb proliferation,
- Freeze North Korea's nuclear program,
- Halt and reverse the development of nuclear weapons in South Asia,
- Achieve a global fissile material production cutoff,
- Safeguard highly enriched uranium and weapon-grade plutonium stocks,
- Decrease highly enriched uranium inventories by conversion to low enriched uranium for reactor use,
- Encourage the use of most proliferation resistant fuel cycles in the nuclear power industry and in research reactors worldwide, and
- Promote safe and secure disposition of plutonium.

Chemical and biological weapons nonproliferation goals include:

- Achieve full implementation of the Chemical Weapons Convention (CWC),
- Strengthen the Biological Weapons Convention (BWC) by means of a Protocol on Verification,
- Eliminate former chemical and biological weapons stocks and facilities world-wide as required under the CWC and BWC,
- Assist Russia in the destruction of its chemical weapons,
- Control chemical and biological weapons-related technologies, and
- Monitor dual-use technologies.

U.S. nonproliferation policy includes a strong commitment to regional security. This includes, for example, preventing Iran and Iraq from acquiring weapons of mass destruction and ballistic missiles. It also includes promoting stability in South Asia by persuading India and Pakistan to abjure nuclear weapons testing, forego destabilizing nuclear and missile activities, and, ultimately, accede to the NPT. Another major component of U.S. nonproliferation policy is to redirect the efforts of former Soviet weapons scientists to peaceful endeavors

DOE's Role in Nonproliferation Policy

The Department of Energy is not only a participant in the making of nonproliferation policy; it has a major role in implementation as well. There are both historical and technical reasons why weapons of mass destruction proliferation prevention is one of the Department's most critical missions.

Nonproliferation activities at DOE are carried out principally in the Office of Nonproliferation and National Security (NN), Defense Programs (DP), Fissile Material Disposition (MD), and the Office of Intelligence (IN). Each of these entities depends heavily on the DOE national laboratories for technical expertise, including assessments of technical requirements and viability related to nonproliferation policy.

The NN Office will be included in the mission of the National Nuclear Security Administration (NNSA), which is to be established in March 2000. The *Department of Energy National Nuclear Security Administration Implementation Plan* (January 1, 2000) outlines organizational changes relevant to NN, as follows:

> "The Office of the Assistant Secretary for Nonproliferation and National Security will be re-designated as the Office of the Deputy Administrator for Defense Nuclear Nonproliferation. The Office of Fissile Materials Disposition will be incorporated within this Office. The Assistant Deputy Administrator for Fissile Materials Disposition also will serve as the Special Secretarial Negotiator for Plutonium Disposition.
>
> The Implementation Plan provides that, in general, employees currently funded under either the Nonproliferation and National Security or Fissile Materials Disposition program direction accounts will be designated as employees of the Administration. Their roles and responsibilities will remain essentially unchanged, focusing on the continuing missions of the programs. The Deputy Administrator will carry out the duties specified in the section 3215(b) of the NNSA Act. Pending confirmation of a Deputy Administrator, the current Assistant Secretary for Nonproliferation and National Security will serve as the Deputy Administrator."

DOE derives its fundamental authority in the nuclear nonproliferation area from the Atomic Energy Act of 1954, as amended, together with a host of additional statutes that address matters including protecting national security information, controlling exports of WMD-related materials and technology, and preserving the environment. U.S. obligations under international treaties and agreements that seek to control, reduce, or eliminate WMD and protect the interests of the United States and its citizens often produce additional nonproliferation and verification responsibilities for the DOE, due to its unique capabilities and expertise. Presidential statements of policy and guidance, issued in the form of Executive Orders and Presidential Decision Directives, are another source of the Department's policy mandate.

DOE has dual responsibilities with respect to nuclear weapons: (i) sole responsibility for research, development, and stewardship of nuclear weapons, and (ii) lead responsibility for nuclear nonproliferation technology. These twin responsibilities derive from and draw heavily upon the base of expertise and knowledge resident in the DOE nuclear weapons complex and the broader system of national laboratories operated by DOE. (Here, and throughout this report, we use the term "DOE national laboratories" to refer all DOE laboratories that are officially titled national laboratories as well as DOE facilities that have technical expertise directly related to the nonproliferation mission, such as Ames Laboratory, Environmental Measurement Laboratory, Remote Sensing Laboratory, Savannah River Technology Center, and the Special Technologies Laboratory.) The Department's influential role in nuclear nonproliferation policy derives from this capabilities base. DOE participates in virtually every aspect of nuclear nonproliferation policy formulation and implementation.

The Department's involvement in chemical and biological weapon nonproliferation policy is more recent, but has historical roots as well. The need to understand the effects of ionizing nuclear radiation on biological systems led to the development over time of substantial biological expertise at many DOE laboratories. A multitude of other program needs--some nuclear related, some environmental, and some opportunistic--led to the development of chemical expertise within the DOE laboratory system as well.

Over the decade of the 1990s, concern that biological and chemical weapons might be used by states or terrorist groups with animosity toward the U.S. or its allies has become a major national security issue. The chemical and biological expertise resident in the DOE national laboratories, together with DOE's long experience in (nuclear) nonproliferation policy and technology, resulted in the Department being recognized as an able, effective, and indeed critical, participant in developing national strategy and technology to confront the new threats. DOE's role in chemical and biological weapons nonproliferation policy development is shared with many other federal agencies. DOE's technology role is focused primarily on technology against the domestic chemical and biological terrorism threat, but there is much synergy between the domestic problem and the battlefield chemical and biological threat for which the Department of Defense has the lead.

DOE Office of Nonproliferation Research and Engineering

One of DOE's most important nonproliferation roles is the sponsorship of an extensive R&D program under the Office of Nonproliferation Research and Engineering (NN-20). A large fraction of that work is carried out at the DOE nuclear weapons laboratories: Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. Other DOE laboratories—including Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Engineering and Environmental Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Remote Sensing Laboratory, the Savannah River Technology Center—as well as selected industries and universities also make important contributions to nonproliferation technology under NN-20 sponsorship.

The NN-20 Office is the predominant government entity responsible for the development of nonproliferation technology. NN-20 manages a program of approximately $220 million per year for science and engineering programs in support of nonproliferation, intelligence, arms control, and national security technologies.

NN-20's research and development program is focused on identifying basic and applied technologies that have promising nonproliferation and national security applications and advancing them to the prototype stage. The Director of the NN-20 Office co-chairs the interagency Nonproliferation and Arms Control Technology Working Group (NPAC TWG), which is responsible for coordinating government-wide research and development in the area of arms control and nonproliferation. The NPAC TWG reports equally to the relevant NSC policy IWGs and the Council on National Security (CNS) within the National Science and Technology Council (NSTC) structure, and is the most important forum in which the work of NN-20 is vetted with DOE's interagency national security partners. Because of its ready access to the expertise resident in DOE's national laboratories, NN-20 is often relied upon by the interagency community to address the most difficult nonproliferation requirements. NN-20 is also called upon by the interagency community when quick, technical answers are needed to critical questions related to nonproliferation and national security.

The objectives of NN-20 are to develop, test, and demonstrate:

- Technologies that can locate, identify, and characterize nuclear explosions underground, underwater, in the atmosphere, and in space in accordance with U.S. National Technical Needs and verification requirements for nuclear test ban treaties;

- Technologies needed to detect by remote means the early stages of a proliferant nation's nuclear weapons program;

- Radiation detection technologies for nuclear materials protection, control and accounting, nuclear warhead dismantlement, law enforcement forensics, and intelligence support;

- Technologies capable of detecting and deterring the diversion and smuggling of nuclear weapons and special nuclear materials; and in partnership with other agencies,

- Advanced technical capabilities that can dramatically improve the U.S. domestic capability to prepare for, detect, and respond to chemical and biological terrorism.

The technical objectives listed immediately above are integral to the U.S. nonproliferation and arms control strategy described earlier in this section. The goals are to advance existing detection capabilities for all types of WMD, to make it possible in the future to carry out monitoring functions that are not feasible now, and to understand the technical limits of both non-cooperative and cooperative monitoring approaches. The NN-20 program is responsive to the goals and needs of U.S. nonproliferation policy and is coordinated with the national security community by means of the interagency NPAC TWG and other means.

NN-20 objectives are currently carried out within the following four principal research and engineering program areas of NN-20's R&D portfolio:

- Nuclear Explosion Monitoring--developing sensors and systems that enable the U.S. to monitor nuclear explosions in any medium and at any place using national technical means and to support U.S. international obligations.

- Proliferation Detection--developing remote sensors and sensing systems to detect the physical signatures of nuclear proliferation as well as effluents from facilities that might be associated with nuclear processes. (Some of these technologies may also have application to detecting chemical and biological weapons proliferation.)

- Proliferation Deterrence--developing on-site and off-site detection and analysis systems for micro-samples of material obtained cooperatively or by other means from a site or facility that might be associated with nuclear proliferation. (Some of these technologies may also be applicable to chemical and biological weapons nonproliferation.)

- Chemical and Biological Nonproliferation--developing technologies and integrated systems that will increase U.S. domestic preparedness against terrorist acts involving chemical or biological agents.

As part of the larger U.S. Government research and development portfolio, the NN-20 R&D portfolio is subject to the broad tenets of U.S. science and technology policy. Among these are: expanded use of independent review to ensure quality and the development of partnerships with universities and the private sector.

Based on the foregoing analysis of the Department of Energy's role in nonproliferation and its technical capabilities, the Advisory Committee reviewed the NN-20 portfolio to determine how well it addresses nonproliferation and national security objectives, meets high standards of technical quality, satisfies the needs of end-users, and constitutes a balanced program.

2: Relationship of Policy to Technology in NN

The Policy-Technology Partnership

The effectiveness of arms control and nonproliferation policies has historically depended on understanding and mastering technology. The capabilities of science and technology have frequently shaped the content of U.S. efforts in arms control and nonproliferation during the cold war. More specifically, in almost all cases it was the efficacy of national technical means of verification that determined the kind of strategic offensive arms limitations possible and acceptable to treaty signatories.

In the 1980s, the advancement of on-site hydrodynamic yield measurement techniques (CORRTEX) by scientists and engineers at the DOE weapons laboratories provided a complementary verification technology to traditional teleseismic verification, and thereby facilitated ratification of the Threshold Test Ban Treaty (TTBT) and Peaceful Nuclear Explosions Treaty (PNET) by the United States. In addition, work conducted over four decades by scientists and engineers in the academic community, industry, and the DOE laboratories has greatly improved teleseismic capabilities for nuclear explosion monitoring. More recently, regional seismic research and development have further improved those capabilities.

Technical experts who understand the policy dimensions of the arms control process have always been essential to formulating and implementing effective arms control and nonproliferation policy. The number of scientists and engineers in the arms control and nonproliferation community within the U.S. Government has declined in recent years. This is especially unfortunate given that many of the “easy” arms control and nonproliferation measures have now been achieved. The next steps in the WMD nonproliferation effort will require more sophisticated solutions to the implementation and verification challenges and even tighter integration of technology and policy.

The next round of strategic arms reductions is expected to call for the number of strategic nuclear weapons to be reduced well below the levels of the Strategic Arms Reduction Treaty (START) II. In addition, the past practice of limiting and reducing launchers, missiles, or aircraft (large items) rather than warheads (small items) will not be adequate, even with the end of the cold war. Actual warheads will have to be counted, tracked, and verifiably disassembled. If even lower numbers of nuclear warheads are negotiated at a future date, the U.S. must be able to verify that other states do not have large unaccounted nuclear warhead stockpiles or significant fissile material reserves. The ability to be certain that no hidden stockpiles exist will be critical for a United States that has deeply reduced its nuclear forces. The challenge is to develop verification technologies that produce meaningful data yet protect classified nuclear weapon design information.

There are numerous other examples of the need for technical expertise in formulating and implementing arms control and nonproliferation policies. The U.S. appears certain to want to improve its capability of detecting nuclear tests at yields below the values that have been achieved to date. The development of more sensitive detection and verification tools will require scientists who are able to understand the strengths and weaknesses of possible evasion schemes. Although the technical issues are entirely different, a similar situation exists for the Chemical Weapons Convention (CWC) and the Biological Weapons Convention (BWC). Both of these treaties are currently difficult to verify and may become increasingly so as dual-use technologies become more broadly available. However, not all trends are unfavorable. Sensor miniaturization, signal processing capabilities, global communications, DNA sequencing identification for biological materials, and other technological advances are likely to open new possibilities for detection, verification and intelligence collection.

In short, the future will require more, not less, attention to technology for arms control, intelligence, and nonproliferation purposes. This comes at a time when the scientific expertise within the U.S. Government is decreasing, especially in the policy community. How can the United States take maximum advantage of technology to solve the new challenges if there is little systematic and organic connection between the policy and technical communities? How will the policy community grasp the technical possibilities for meeting today's and tomorrow's challenges if there is no way for the policy community to keep up-to-date on scientific advances? The technical community needs to be present at the deliberations of the policy community.

Leadership Role for NN

DOE has a unique opportunity and affirmative responsibility to bridge the nonproliferation policy and technology communities, not only within the Department but also in the U.S. Government generally. Both communities come together in NN, the only entity in a major governmental agency in which policy, implementation, and technology are combined. No other agency is so appropriately structured and no other agency has such ready access to the expertise present in the DOE national laboratories.

The Office of Nonproliferation and National Security should take greater advantage of its position to facilitate the integration of technology and policy. Too few of the technologies that NN-20 is sponsoring are linked to DOE policy offices that have representatives on interagency policy groups and task forces. NN has the mission to serve both DOE and the broader national security community, but a proper balance needs to be maintained.

There are good examples of successful integration of policy and technology within NN, and we recognize and applaud these accomplishments. For example, NN policy experts have made and continue to make extensive use of NN-20 funded work at the DOE laboratories to solve the daunting verification problems raised by START III. Another example of a successful policy and technology integration within NN is the strategic plan for the role of the DOE community in the national response to the threat of domestic terrorism by chemical or biological means. The plan lists the primary technical capabilities that need to be developed through a cooperative effort between DOE/NN, Department of Defense, Health and Human Services, and the investigative and disaster response agencies. The strategy includes detection, prediction, restoration and recovery, therapeutics, forensics, and systems analysis. The plan enumerates programs in each area. However, even here there is something missing: the plan is silent as to what technical products are expected and on what time-scales.

The implementation of export controls on information (knowledge) is an area in great need of assistance from the technical community. NN has the responsibility, exercised through its NN-43 Program, to publish lists of "sensitive unclassified technical information" and export controlled information. The lists published to date in both categories are highly simplistic, damaging to the performance of technical work, and of no benefit to national security. The terms used in these lists are so broad and ill-defined that technical performers have no way to judge whether their careers will be in jeopardy if they discuss unclassified subjects in ordinary work situations where foreign nationals may be present, such as meetings of professional societies.

The activities of NN-43 in promulgating lists of unclassified but export-controlled items should be subject to review by representatives from the scientific community within NN. In case of conflict, the NN Science Advisor should be called in to either settle the matter or refer it to higher authority in DOE.

Strengthening the Policy-Technology Partnership

The technology programs of NN-20 and associated DOE laboratory scientists and engineers appear to have insufficient institutionalized contact with the policy and implementation divisions of the interagency community. This restricts the flow of technical knowledge and information about NN-20 R&D programs out to the larger community and the reverse flow of information from the policy community about its emerging needs and the shortcomings of current technology. If the need for a more substantive interaction between the two communities is left unaddressed, DOE's influence at the interagency working level will erode at the very time the policy community needs improved access to the technical community.

NN should take explicit steps to ensure greater two-way interactions between NN-20, the NN policy offices, and the wider interagency community. An initiative consisting of multiple elements is most likely to succeed.

A mechanism is needed to insure greater integration between policy and technology within NN itself. For example, it would be useful to institute a process by which the policy divisions of NN would formally articulate their needs and their impressions of the needs of the interagency community at an early stage of development of the budget for the NN-20 R&D portfolio. NN-20 program managers would respond in turn with their plans to address those needs. These documents should not be complex and should be coordinated by NN-1. At a later stage in the process, members of the interagency Nonproliferation and Arms Control Technical Working Group (NPAC TWG) could be invited to offer comments and advice on plans for the NN-20 R&D portfolio.

Other integration steps within NN could be less formal and separate from the budget process. For example, NN-20 together with representatives from the DOE laboratories could provide NN policy offices with information about new opportunities emerging from technological advances. The policy offices could in turn report to NN-20 what technologies are being used and where improvements or new capabilities are needed. Representatives from the larger interagency community could be invited to join in those exchanges.

The interagency policy community outside of DOE also needs to be involved in the integration process. Few communications from the science and technology community to the policy community comprehensively describe the status of R&D efforts that address current objectives for verification and nonproliferation technologies. There is a serious lack of understanding in the policy community about the potential for technological advances beyond current objectives, the possibilities of fundamentally new capabilities, or the technical limitations of current and prospective technologies.

NN should assume the responsibility for communicating to the interagency policy community both the *limitations* and the *potential* of science and technology to meet nonproliferation, intelligence, and verification objectives. This information, which we shall refer to as the Annual Nonproliferation Technology Assessment, should be made widely available within government in the form of a short classified annual report or an equivalent communiqué. The NN Science Advisor should assume overall responsibility for the assessment, with major contributions coming from NN-20 and the DOE laboratories with expertise in nonproliferation, intelligence and verification.

An Annual Nonproliferation Technology Assessment would enable more coherent R&D goals to be formulated for the U.S Government generally, and for the NN-20 Office in particular. It would also give the policy community a better understanding of what technology is being developed and what to expect from it. By documenting the close synergy between technology and policy, NN can demonstrate the value of its R&D program more effectively to both the Executive and Legislative branches and gain the long-term support needed to address tomorrow's challenges.

Our recommendations are not meant to imply that all projects in NN-20 R&D portfolio must be directed to specified goals. On the contrary, we believe that management of the NN-20 R&D portfolio should reflect a balance between two distinct responsibilities. NN should provide strong encouragement for *decentralized initiatives* within the technical community for developments that will advance nonproliferation and national security technologies. At the same time NN must also provide technical support of the near- and long-term objectives of the policy community. Improved communication between the policy and technical communities is essential to the success of future nonproliferation and national security efforts.

3: End-Users of NN Technology

A Multidimensional Relationship

The R&D portfolio of the Office of Nonproliferation Research and Engineering (NN-20) serves a diverse set of end-users: Department of Energy, Department of Defense, Intelligence Community, Department of State (Arms Control), Department of Justice (FBI), and Customs, among others. As the NN-20 Chemical and Biological Nonproliferation program develops, this list is growing to include state and local law enforcement, emergency response, and public safety authorities. This diverse environment—intrinsic to the nonproliferation problem—makes the task of transferring the knowledge and technology created by NN-20 to end-users especially challenging.

The technical products of NN-20's work on nonproliferation and national security problems must be transferred to end-users. Successful transition of technology may be the most difficult of all the responsibilities incumbent upon NN-20. In some program areas, the current modes of interaction between NN-20 and end-users of its technology are the products of long-term relationships well understood by all parties involved and very successful. In other program areas, current relationships appear ad hoc, idiosyncratic, and fragile.

Existing practices for NN-20 interactions with end-users need to be given greater visibility and articulation within NN and also in the wider interagency community.

Strengthening the Relationship

The Annual Nonproliferation Technology Assessment, recommended as a means of improving substantive communications between the science and technology community and the nonproliferation policy community, will also facilitate NN-20 interactions with end-users. In addition to the assessment, NN could offer periodic briefings (once or twice a year) to potential end-users to keep them aware of what might be possible in their fields of endeavor and to provide a forum for the end-users to inform NN-20 of their needs and experience with existing technologies.

The adoption of the "merit review" approach we recommend would further assist in keeping end-users in mind in NN-20 project selection and reviews. Inviting representatives from the end-user community to participate in these reviews on a regular basis, as NN-20 does already in some cases, would also be beneficial.

Some NN-20 programs may lend themselves to a scenario-based approach to determine what attributes and capabilities of a proposed technology are necessary to make it most useful to the end-user. Scenarios naturally facilitate early end-user involvement. End-users need to be involved in selecting "credible" scenarios and in playing through them. The NN-20 Chemical and Biological Nonproliferation program appears to be making good use of this approach. But more is needed.

Communications with potential end-users should be opened as early as possible for each new project and continue through all the phases (research, development, and demonstration) for which NN-20 is responsible. Well before a project matures, the planning should include the technology transfer. Obviously, binding agreements cannot be expected at early stages of a new technology and the prerogatives of the end-user decision-making process must be respected. Nonetheless, substantive technical exchanges and memoranda of understanding can be very helpful. Projects in which the end-user provides partial support in funding or in kind are clearly ideal, but NN-20 should not require this. It would be impractical and self-defeating.

Exceptions to the general rule that end-users should be involved in NN-20 projects at the early stages must be allowed, and guidelines clearly defining them should be established. One important class of exceptions should be small, exploratory projects designed to see whether a technical idea with a plausible application to an NN mission is feasible. We refer to such research as “advanced concepts.” For advanced concepts, there is no need to engage an end-user until technical feasibility has been proven.

As in the past, cases will arise in the future where a potential end-user loses interest in an NN-20 project already underway and no other interested party comes forward. In such cases, NN-20 should terminate the project. Conversely, there will also be cases where the end-user remains interested but the cost, capability, or time-scale of the project changes such that it no longer justifies NN-20 support and must be cancelled. As in any relationship, good communications cannot guarantee happiness, but they help minimize surprises.

Operational Equipment

There is one exception to the general rule that NN-20 does not carry the development of technology into the manufacturing stage. The exception applies to the specialized satellite-based sensors that detect nuclear explosions in the atmosphere or in space. These sensors are deployed as secondary payloads on infrared early warning Defense Support Program (DSP) satellites and on the satellites of the Global Positioning System (GPS).

Having DOE manufacture the operational nuclear detonation detection system (NDS) packages for satellites is a legacy reaching back to the VELA era when satellites dedicated *solely* to the task of detecting nuclear explosions were deployed following the signing of the 1963 Limited Test Ban Treaty. This practice has a long and successful history, and many generations of NDS improvements using NN-20 technology have been deployed. Nevertheless, the practice is an anomaly. For the next round of NDS improvements, DOE laboratories will be manufacturing instrumentation for as many as 24 to 30 operational units to be carried on the next generation Block IIF GPS satellites.

A careful study should be done of the current practice of having DOE manufacture NDS operational packages. The study should involve the participation of all stakeholders. The key question should be: What approach is best for the country?

The study should determine whether or not it would be better to follow a model similar to what NN-20 does in the rest of its portfolio. Namely, NN-20 would be responsible for the research and development of new generation NDS packages through the prototype demonstration and testing stages and then turn the drawings and specifications over to an industrial manufacturer selected on a competitive basis. DOE scientists and engineers would remain involved as consultants to resolve problems that arise in manufacture and assist with liaison to the Air Force Project Office responsible for the GPS system. This approach would be analogous to the way that Lincoln Laboratory transitioned EHF satellite communications technology to industry after first successfully demonstrating it on experimental satellites. Whatever the conclusions of the study, current schedules for NDS upgrades for GPS should not be disrupted.

End-Users of NN-20 Technology

AFTAC

The Air Force Technical Applications Center (AFTAC) is a long-term end-user of the technology developed by the NN-20 Nuclear Explosion Monitoring program. AFTAC has the operational responsibility for ground-based and satellite-based sensor systems that provide national technical data for verification of nuclear test ban treaties and nuclear explosion monitoring. NN-20 is for all practical purposes the sole developer of technology for the Center.

NN-20’s relationship with this end-user is very solid--a success story of several decades. This success has been facilitated by the fact that the treaties supported by this program generally provide well-defined technical verification requirements and involved the technical community, including NN-20, in the development of those requirements. Further contributing to the success has been the high priority the United States has always given to treaty verification. Historically, full and reliable levels of funding for treaty monitoring technology development have existed. AFTAC regards its relationship with NN-20 as excellent.

Intelligence Community

Another major user of NN-20 technology is the U.S. Intelligence Community (IC), which has responsibilities for verification of nuclear arms control treaties and identifying activities indicative of the proliferation of weapons of mass destruction. The IC is a potential end-user of the remote sensing technologies being developed by NN-20's Proliferation Detection program to detect (before actual nuclear testing occurs) signatures of a nuclear weapons program. The micro-sample material identification technologies being developed under NN-20's Proliferation Deterrence program are also likely to be of interest to the IC. The primary focus of both the NN-20 Proliferation Detection and Proliferation Deterrence programs is nuclear proliferation, but several of the technologies under development, if successful, may have applications to chemical and biological proliferation, provided reliable signatures exist at detectable levels.

The relationships between the IC as an end-user and NN-20 as a technology provider are complex. They range from analysts needing help from DOE laboratory scientists to interpret data, to communications with members of the IC seeking new collection capabilities. End-users in the IC find their relationship with NN-20 valuable and important.

DoD/DTRA

The Defense Threat Reduction Agency (DTRA), which has responsibility for on-site inspections and monitoring activities established by treaties and other agreements, receives many types of technical assistance from NN-20. Past examples include the on-site inspection technology applied to the Intermediate Nuclear Force Treaty (INF), and technologies to assess the contents of chemical warheads without disassembly in support of the Chemical Weapons Convention (CWC). In addition, monitoring technologies are being developed by NN-20 to support bilateral agreements with Russia for safe storage of fissile materials. DTRA itself funds work at the DOE laboratories, drawing upon the same technical expertise in the chemical and biological areas that supports the NN-20 Chemical and Biological Nonproliferation program; such practices build useful bridges. DTRA finds its cooperative relationship with DOE and the support it receives from NN-20 highly beneficial.

Interagency Nonproliferation and Arms Control Policy Community

A current example of the role of NN-20 and the benefit provided to the interagency arms control community is the monitoring requirements of prospective further reductions in strategic offensive nuclear arms. Although the START I and START II treaties reduced the number of deployed nuclear warheads, the principal focus of verification in both treaties is the delivery vehicle--heavy bomber, submarine, or ground-based ballistic missile--not the warhead itself. If future treaties call for even lower warhead limits, verification will have to expand to include actual warheads. It is likely that the U.S. will need to monitor the actual number of warheads in stockpiles, and assure itself that warheads removed from stockpiles are being dismantled and their fissile components disposed of safely and securely. These new verification requirements will pose formidable technological challenges.

Whereas delivery vehicles are large and amenable to detection by national technical means, warheads are small and can readily be concealed. A special warhead protocol may be necessary to verify that an object declared to be a nuclear warhead is in fact a nuclear warhead, or an object declared not to be a warhead is not a warhead. Although technologies such as radiation detection can help monitor such a protocol, they must do so without revealing sensitive information about the design of the warhead being examined. The limits of what can be determined about warheads, given this requirement to protect sensitive information, are being explored by NN-20. These studies are being conducted on actual U.S. warheads and associated components to determine the limits of applicability and the difficulties that could be encountered in a prospective warhead dismantlement regime. Simulated treaty inspection regimes have been conducted at the U.S. warhead dismantlement facility using candidate equipment developed in response to requirements set by the U.S. policy community.

The development of innovative equipment under NN-20 funding, and its exercise under simulated treaty conditions, provide the interagency arms control community with “ground truth” regarding what presently can and cannot be done. No other part of the interagency community has the expertise, understanding, equipment, and access to warheads and facilities that the DOE/NN can bring to bear. The information gained from these exercises is critical to today’s interagency policy formulation as the U.S. seeks to establish its position with respect to a potential START III Treaty. This research will also help the United States to prepare for other future arms control negotiations, and will identify future research and development requirements for additional progress in this area.

Department of Justice/FBI

The relationship between the Department of Energy and the Federal Bureau of Investigation (FBI) Laboratory is facilitated by a Memorandum of Understanding signed in 1998. A vast array of state-of-the-art material identification technologies and other capabilities exist at the DOE laboratories that are potentially valuable to the FBI. Many of the technologies that NN-20 is pursuing in its Chemical and Biological Nonproliferation program will also be valuable to the FBI.

The basis of a very productive relationship between NN-20 and the FBI is in place. Stable funding for NN-20's work with the FBI is needed to realize the full potential of this relationship.

State and Local Law Enforcement

Several areas of the NN-20 portfolio comprise expertise and technologies of high value to local law enforcement agencies. Among these are sample collection and analysis capabilities, field analysis instrumentation, and laboratory micro-sample analytical capabilities. Virtually all of the multi-purpose DOE national laboratories have material identification technologies superior to those available to local and state authorities.

NN-20's Chemical and Biological Nonproliferation program (CBNP), whose goal is to improve domestic preparedness against the threat of domestic terrorism involving chemical or biological agents, is also highly relevant to local end-users. Part of the program’s mission is to develop tools and technologies for "first responders" (fire, police and other local safety personnel). DOE laboratories participating in the CBNP program have made contact with regional representatives. Over the next two years the program will also be conducting several large demonstration projects that will give valuable experience in working with local and state authorities. Technology demonstrations and data collections at an underground station of the Washington, D.C. Metro system, at the new international terminal at San Francisco Airport, and at the 2002 Olympics in Salt Lake City are currently planned.

Currently, the relationship between NN-20 and state and local authorities comes primarily through the Chemical and Biological Nonproliferation program. It appears to be developing well. In the long run the asymmetry between the large numbers of potential local users and the relatively small number of DOE laboratories will need to be addressed.

4: NN-20 Project Selection and Review Processes

Introduction

In this section we discuss the project selection and review processes NN-20 currently uses to ensure the technical quality and mission relevance of its R&D portfolio. We then discuss ways in which these processes can be strengthened.

The quality of the NN-20 R&D portfolio is essential to achieving U.S. nonproliferation and national security goals. The NN-20 R&D portfolio is primarily a mission-driven research and development portfolio, shaped by national policy and end-user needs. Much of the work of the NN-20 R&D portfolio is carried out at the DOE national laboratories.

The portfolio operates over the full range of the research and development spectrum: directed-basic research, applied research, and prototype development. It supports both short-term requests and long-term development. A portion of the portfolio also supports exploratory funding of new ideas that might lead to revolutionary advances in nonproliferation and national security technologies, but this activity has suffered in recent years due to funding constraints.

Although NN-20 is always the primary source of funding for the projects in its R&D portfolio, it is not always the sole source. Some technology projects in the NN-20 portfolio began with DOE Laboratory Directed Research and Development funding, DOE Office of Science support, or funding from a non-DOE source. At the end of the technology development cycle, prospective end-users sometimes contribute partial funding for a prototype, help in kind by providing platforms (e.g., aircraft, space launch), or invite an NN-20 project team to gather data with instruments at a field exercise the end-user is sponsoring.

The current project selection and review processes used by NN-20 to manage its R&D portfolio have evolved as an adaptation to the environment in which the Office operates. It does not currently use a common set of project selection and review processes across the entire portfolio.

Current Selection and Review Procedures

At the request of the Advisory Committee, RAND prepared a summary of current NN-20 selection and review processes. (Reproduced in Appendix E of this report.) In addition, the Advisory Committee had direct discussions with NN-20 officers and individuals at the DOE laboratories about current selection and review procedures.

There are a number of features common to the project selection and review processes of the NN-20 R&D portfolio. Most NN-20 research projects are selected as part of an annual budget planning process involving DOE/NN-20 headquarters and the DOE national laboratories. Each year in response to a memorandum from the Director of NN-20, laboratories submit Project Lifecycle Plans (PLPs) and prioritize proposed new research and development efforts and currently funded projects. (A copy of that memorandum, sometimes referred to as a "call for proposals," is also included in Appendix E.) Each of the PLPs is targeted to one of the four NN-20 program areas and includes a projection of funding needs over the next five fiscal years. Detailed statements of work are provided for each project (proposed and existing), describing its potential contribution to NN-20 R&D program goals, scientific and technical merit, and specific tasks to be accomplished. NN-20 program staff, together with end-users and sometimes outside experts, review the PLPs and make recommendations concerning the selection of new projects and the continuation (or termination) of existing projects. The Director of the NN-20 Office has responsibility for the overall portfolio.

NN-20 also interacts with the policy offices of NN; with DoD, especially the Office of the Secretary of Defense (OSD)/Policy and the Defense Threat Reduction Agency (DTRA); and with other members of the nonproliferation and national security community. These interactions often impact NN-20 R&D planning, sometimes launching efforts in areas where firm requirements do not yet exist but where technology needs to be developed.

All NN-20 projects are required to submit quarterly reports, indicating technical progress to date, problems, milestones and schedules, and costs. These reports are augmented by direct contact between NN-20 staff and the project principal investigators (PIs) and their program managers at the laboratories. These meetings take place 2-3 times per year for all projects and result in status reports of varying degrees of formality. In addition, each project is subject to a formal program review each year, in which the PI makes a structured presentation to the NN-20 staff.

Strengthening Selection and Review Processes

Because its R&D portfolio supports a broad range of activities and serves a diverse set of end-users, NN-20 should not use a single set of project selection and review processes for the entire portfolio. It should, however, apply a set of universal principles. Selection and review processes should be chosen to ensure the highest possible *scientific and technical quality and program relevance.* The particular selection and review processes used for a project should be appropriate to the nature of the project and the program area to which it belongs.

Merit Review

Peer review is a process developed and used extensively in the academic world for basic research. The process is defined by the use of an independent group of experts in the discipline or disciplines encompassed by a proposal. Traditionally the criteria for selection and funding are weighted exclusively on the scientific and technical quality of the work. A modification of peer review, termed “merit review,” expands criteria beyond scientific and technical quality to include program relevance.

NN-20 should expand its use of external merit reviews in project selection decisions and subsequent progress reviews, including it wherever feasible in managing its R&D portfolio. For NN-20 the principal criteria should be: (1) scientific and technical quality, and (2) potential contribution to nonproliferation and national security goals. The manner in which a project would be required to demonstrate its contribution to the NN-20 mission should depend on its position on the R&D continuum and the nature of the program areas to which it belongs. Additional criteria drawn from a quality assurance perspective should be added for projects that are more directed or end-user focused.

When selecting new projects for the NN-20 R&D portfolio, merit review would include a solicitation for proposals, evaluation by NN-20 staff members for responsiveness to the solicitation criteria, and, for all proposals that meet solicitation criteria, review by an independent panel of experts. The criteria used to judge merit should include the two principle criteria listed above and appropriate special criteria. The panels, which would meet with the respective NN-20 program manager, would make recommendations to the Director of the Office of Nonproliferation Research and Engineering. For classified projects, the available pool of independent experts will be smaller than for unclassified projects, but merit review panels should always include individuals from outside of NN-20 and the DOE national laboratory community.

The NN-20 Chemical and Biological Nonproliferation program area has adopted merit review for project selection and should continue the practice. The satellite-based sub-area of the Nuclear Explosion Monitoring program area, where the nature of the work is long-term and there are explicit requirements to provide sensor packages matched to the satellite systems interfaces on specific timelines, has long used a merit review process that includes criteria specific to the needs of its end-users; it should continue to do so.

The Proliferation Detection and Proliferation Deterrence program areas of the NN-20 R&D portfolio and the ground-based portion of the Nuclear Explosion Monitoring program area should adopt the merit review approach. Adopting merit review across the entire NN-20 R&D portfolio will pull together good practices already in place, will strengthen practices that are now weak, and will provide a coherent framework for articulating the portfolio to the community inside and outside of DOE, including prospective applicants and end-users.

Laboratory-Level Reviews

Most DOE national laboratories have laboratory-level and directorate/divisional level reviews conducted by outside panels on a regular basis (usually annually). A significant component of these reviews is an assessment of the scientific and technical work being conducted by the laboratory, including NN-20 funded projects. The exact format of these annual reviews, the composition of the panels, and the reports that result differ according to contractual requirements and laboratory policy. Sharing the results of laboratory reviews with NN-20 administration is not done on a formal basis, but informally the NN-20 should be advised about the outcome of these reviews.

DOE headquarters and the DOE laboratories can and should maintain separate domains of accountability. DOE Headquarters should focus its attention on initial project selection, end-user needs, integration of technology and policy, and interagency education. Headquarters should rely more on the science and engineering review processes at the laboratories than it currently does for making judgments about the technical progress of approved projects, provided these reviews are done in a manner that is clearly articulated and include technical experts from outside the laboratory. For multi-laboratory projects, or when significant technical or budgetary problems arise in a previously approved project at a single laboratory, a combination of headquarters and laboratory reviews would be appropriate. Annual reviews of all projects by NN-20 should continue; redundant reviews should be avoided.

Transparency and Documentation

Selection and review procedures should be *transparent, consistent, and documented*.
Overall, there is a lack of formality (systematic documentation) in current NN-20 project selection and review processes. Current practices are too highly program area dependent, and there is insufficient tracking and transparency in the management of the NN-20 R&D portfolio. With some key exceptions, it was difficult to find a clear, documented description of the selection and review process used in each individual program area.

The ready availability of comprehensive information on NN-20's project selection and review processes across the portfolio would be useful to DOE laboratory program managers and researchers and to outside researchers who may be interested in collaboration with laboratory scientists or becoming principal investigators on their own right. The specific criteria used in merit review selection processes should be spelled out clearly in all calls for proposals or equivalent documents.

Many NN-20 projects deal with classified technical information, applications, or polices. For these projects, "transparency " and "documentation" will often need to take the form of classified calls for proposals, reports, and reviews. Nevertheless, these classified documents should be available to those who have the necessary clearances and need to know.

Expanding Participation in the NN-20 R&D Portfolio

To be most successful, the NN-20 R&D portfolio must draw upon all the resources of the U.S. science and technology enterprise, while safeguarding classified and other sensitive material and information. At the same time, DOE generally and NN-20 in particular, have responsibility for the stewardship of the technical nonproliferation and national security capabilities of the DOE national laboratories. Balancing these perspectives is a continuing challenge for NN-20.

There needs to be greater opportunity for the wider U.S. scientific and technical community to contribute to the success of the NN-20 portfolio. This can be done through open competition administered by NN-20 as part of its portfolio solicitation process, and through partnerships chosen and managed by the DOE laboratories. Partnerships in the form of consultantships, sub-contracting, sabbatical visits, etc., involving academic researchers and sub-contracting with industry for development and manufacture are well established practices at the laboratories.

DOE laboratories have a history of interaction with the larger U.S. scientific and technical community. Participation of non-DOE personnel in NN-20 projects has been successful. Work that depends on *unique* capabilities and facilities of the DOE laboratories should continue to be limited to the DOE national laboratories. Program areas of the NN-20 portfolio that are chosen for open competition should be ones in which high expertise already exists in the academic sector and/or the industrial sector and is applicable to the nonproliferation and national security mission.

Some NN-20 project areas lend themselves to outside participation as a result of the high technical state-of-the-art that exists in the academic or industrial sectors. Project areas that come to mind include seismic verification technologies for low yield underground nuclear tests, and chemical and biological agent detection and identification technologies. Other possible areas are specialized electronic chip development and certain radio-frequency technologies.

Over the course of this review, it became apparent that there are numerous examples of current and recent participation by academe and industry in the NN-20 R&D portfolio, but we are uncertain of the actual numbers. Data demonstrating the frequency and nature of non-DOE laboratory participation in the NN-20 R&D portfolio does not exist in any one place.

NN-20 should document more systematically funding that goes directly to institutions outside of the DOE system as well as funding that goes to the DOE laboratories and then goes out to consultants, subcontractors and collaborators. The documentation should be done in a way that distinguishes substantive scientific and technical involvement from routine purchases of equipment or services.

5: Quality Metrics for NN-20 Projects, Programs, and Personnel

The DOE national laboratories were created as partners to the U.S. Government under contracts documenting that partnership, not as contractors in the ordinary sense. Their continued existence requires that they remain centers of excellence and responsive to national needs. In this section we discuss measures of the quality of the research and technology that results from NN-20 work at the DOE national laboratories, its impact on nonproliferation and national security goals, and the quality of the administrative, scientific, and technical personnel involved.

The Challenge

The diversity of the NN-20 R&D portfolio means that no single set of metrics is suitable for all areas. Metrics used to evaluate the quality of NN-20 programs and projects should be chosen in a manner matched to the activity being evaluated. These activities vary from research in highly specialized areas to large multidisciplinary programs for the development of fully engineered systems to be used in the field. In addition, quality indicators for the personnel associated with the NN-20 need to be chosen appropriately.

NN-20 headquarters and administrators at the DOE laboratory complex who manage funds received from NN-20 should work together to identify metrics that will serve as objective indicators of the quality of the work performed and the impact of that work on nonproliferation and national security goals. Records of quality and impact should be kept and reported on a regular basis. Similarly, indicators of the quality of scientists, engineers and program administrators associated with NN-20 work should be gathered and reported regularly.

Quality Metrics for Programs and Projects

The quality of NN-20 projects and programs and their contributions to nonproliferation and national security goals can be referenced to a set of metrics. The set might include, for example:

- Degree to which the project provides the United States with an important new capability.
- Degree to which innovation is required to execute the project (the need to create new sensors, new chips, new processing algorithms, tamper resistant seals, first-of-a-kind device, etc.).
- Degree to which technical performance is advanced by the project (comparison to state-of-the-art technology in sensitivity, speed, power consumption, weight, or other relevant parameters).
- Technical difficulty of the project (degree to which integration of many disciplines is required, number of project subsystems, unique or stressing operation environment, technical risk, etc.).
- Degree to which the project meets or exceeds the end-user's requirements (cost, schedule, and performance).
- Impact and utility of the project (stimulated further technical advancement, used in a field demonstration, successful transfer to end-user, or deployed operationally).

- Prizes, awards, and other recognition received by the project (R&D 100 Awards, high performance in a field trial, patents, commercialization, etc.).

- Management effectiveness (carrying a project to its defined end point, success in running a complex, multi-project program, etc.).

The above list is illustrative, not comprehensive. Only a subset of metrics would be appropriate to a particular project. Metrics for NN-20 program areas should be a composite of those used for individual projects in the program and supplemented by indicators of the degree to which a program is balanced and addresses the overall goals associated with its sector of the NN-20 mission.

Quality Metrics for Personnel

In collecting data indicative of the quality of scientists, engineers and administrators of NN-20 projects, the data should *not* be restricted to work done only on NN-20 projects. A far better way is to look at the full range of the professional work of an individual.

For individuals working at the basic scientific level, publications, invited talks, and research funds received on a competitive basis can be used (the norm in the academic community), but this will be appropriate for only a small part of the NN-20 enterprise. For individuals engaged in applied research and in development activities, metrics that correspond to success in moving projects forward (and for terminating them when initial expectations prove unjustified!) and for marshalling resources across disciplines effectively are needed. So are metrics that capture effectiveness in assembling and managing multidisciplinary teams to accomplish project objectives, and metrics that measure effectiveness of working with end-users. The quality of classified work is often difficult to evaluate and goes unnoticed because the peer groups are often small and security restrictions must be followed. Nevertheless, those factors do not preclude effective and accurate assessment of the quality of classified work; a good faith effort should always be made.

Quality indicators for individuals should include individual prizes for research, technology, other achievements, and testimonials, where appropriate, from end-users of NN-20 technologies. The selection of an NN-20 scientist, engineer, or manager for service on an interagency group, receipt of funding as a Principal Investigator (PI) or co-PI in a Laboratory Directed Research and Development (LDRD) competition, receipt of a patent, etc., should also be included among the quality indicators. Many awards jointly recognize a project and the personnel behind the project (e.g., R&D 100 and Federal Laboratory Consortium Awards); such awards should be counted in both quality categories.

Reports from laboratory-level and directorate/divisional-level external review committees can also be used as a source of information on the quality of programs, projects, and personnel involved at the DOE national laboratories in the NN-20 enterprise, provided such information can be shared outside the laboratory.

Reporting Information about Quality

Information about the quality of NN-20 programs, projects, or personnel should be reported in summary form once a year to the Advisory Committee. Similar information should be included, as appropriate, when reporting about NN-20 programs, projects, or personnel to higher levels in DOE, to the interagency nonproliferation and national security community, and to the Congress.

NN-20 should make it a goal to be able to report with justification *and* documentation that: (1) the work it conducts supports DOE's mission and U.S. national needs, (2) the quality of the science and technology performed is high, and (3) the work is effectively and efficiently managed.

6: Preserving the DOE Nonproliferation and National Security Tech Base

The fundamental scientific and engineering expertise needed to create and develop advanced nonproliferation and national security technologies resides in many parts of the U.S science and technology enterprise. The Office of Nonproliferation Research and Engineering (NN-20) has the task of engaging this enterprise to meet national requirements. The DOE national laboratories play a special role in this regard. (Here, and throughout this report, we use the term "DOE national laboratories" to refer all DOE laboratories that are officially titled national laboratories as well as DOE facilities that have technical expertise directly related to the nonproliferation mission.)

Role of the DOE National Laboratories

The DOE national laboratories provide two essential capabilities for the DOE Office of Nonproliferation and National Security (NN), and NN-20 in particular. First, the national laboratories are often the best, and in some cases the only, source of the specific technical expertise needed for the NN or NN-20 mission. This is especially true for work in the area of nuclear nonproliferation, which demands intimate familiarity with (classified) aspects of nuclear weapons, knowledge of special nuclear materials, identification of signatures of proliferation, and special instrumentation developed for the U.S. nuclear weapons program. The DOE national laboratories also have broad-based expertise in chemical and biological science that is directly relevant to NN-20's responsibilities in the area of chemical and biological nonproliferation. In addition, the DOE laboratories have great depth in numerous key supporting technologies.

Second, the DOE national laboratories provide a secure environment where large-scale, classified experiments can be conducted and classified prototype instrumentation can be developed and tested. The breadth of the science and technology expertise within the DOE national laboratories means that almost any technical area relevant to nonproliferation and national security is present somewhere in the DOE national laboratory system. A wide range of technical disciplines is required to meet NN-20's mission requirements, e.g., radiation detection, spectroscopy, micro-instrumentation, computationally intensive modeling, and fundamental molecular biology. The existence of these capabilities in the DOE national laboratory system allows complex, multi-disciplinary efforts to be assembled and moved into action quickly and effectively. In addition, many technical experts at the national laboratories have experience in addressing problems from a nonproliferation perspective, and are familiar with the relevant national security issues that must be considered.

Maintaining the NN Tech Base

Maintaining the human expertise in nonproliferation and national security technologies that is present in the DOE national laboratories is essential for the future success of the NN-20 R&D portfolio and U.S. nonproliferation efforts. Success requires a highly competent, enduring, integrated research community that understands the scientific and engineering options, the technical details and signatures of weapons proliferation, the needs of end-users, and, most importantly, the ability to anticipate future needs of the U.S. nonproliferation and national security policy community. We call this collective body of scientific and technical expertise and experience the U.S. Nonproliferation and National Security Technology Base (NN Tech Base).

DOE needs to maintain a comprehensive and high quality NN Tech Base in order to be able to meet its responsibilities. Unfortunately, the NN Tech Base in the DOE national laboratories is shrinking due to recurrent under-funding. The NN-20 R&D budget has remained flat for several years at the same time NN-20 has been assigned additional responsibilities. DOE national laboratory administrators, scientists, and engineers have long expressed concern that the NN Tech Base was endangered, but little or no attention has been paid to their concerns. A one-third reduction in the DOE national laboratories' authority to assess programs to fund Laboratory Directed Research and Development (LDRD) budgets in the current fiscal year will further diminish the NN Tech Base. Current trends need to be reversed.

No single federal agency or office can be the sole guarantor of the NN Tech Base. However, the Office of Nonproliferation Research and Engineering (NN-20) has long been a key shareholder through its support of research and development of technology linked to nonproliferation and national security objectives. NN-20 must remain a key shareholder, but cannot do so without the needed resources.

NN-20 should approach its stewardship responsibilities for the NN Tech Base with a three-element program. First, it must continue to sponsor and administer a high quality, forward-looking core R&D program on technologies for nonproliferation and national security that is responsive to end-user needs. Second, a portion of the NN-20 R&D portfolio should be devoted to "advanced concepts" studies. Third, NN-20 should work to enhance professional interactions and communications between the personnel of the NN Tech Base and the broader U.S. scientific and technical community. The first of these elements has already been addressed in previous sections of this report.

The second element, advanced concepts studies, refers to small, high-risk, but potentially high-payoff projects, typically of one to two years in duration. Such projects explore an idea at the fundamental science level to see if it might form the basis of a revolutionary nonproliferation or national security capability. The origin of an advanced concepts study might be an original idea coming spontaneously from the expert knowledge of a member of the NN Tech Base or it may be the outcome of a discussion between a member of the tech base and an end-user or a policy analyst. Advanced concepts research projects need not necessarily have a definite end-user in mind, but should have the potential of contributing to an NN-20 mission, if the results are favorable.

Advanced concepts funding would give scientists and engineers of the NN Tech Base the opportunity to spend a small fraction of their time conceiving and exploring new ideas that may offer fundamentally new and more capable nonproliferation and national security technologies than those currently available or under development—in other words, the opportunity to be creative in an applied context. Funding for advanced concepts is important in its own right, and it would also help attract the best and the brightest of new generations of scientists and engineers to the NN Tech Base.

An NN-20 budget line named "advanced concepts" was lost in recent years as DOE was required to take on new nonproliferation technology initiatives but was not given corresponding increases in its R&D budget. Moreover, in the past, advanced concept projects were often preceded by a year or two of funding at the laboratory level under a Laboratory Directed Research and Development (LDRD) award, another source of support for the NN Tech Base that is shrinking.

DOE should seek increased funding for NN-20 for the support of advanced concepts research on nonproliferation and national security technologies in future years. This might be done in steps starting at a level of 5% of the NN-20 R&D budget and growing to 10% or more over time. Restoration of such funding in the NN-20 portfolio should be a high priority. Failure to do so will have a deleterious effect on the NN Tech Base and DOE's nonproliferation capabilities will erode.

Erosion of the DOE NN Tech Base will also occur if all NN-20 work is driven by the immediate needs of end-users. Focusing exclusively on immediate needs, as has happened at some federal laboratories, inevitably turns innovative programs, such as those in the NN-20 R&D portfolio into evolutionary programs that ultimately become stagnant, predictable, and produce little of real value.

The third element, enhancing professional interactions and communications between scientists and engineers in the NN Tech Base and the broader community, is important for several reasons. Nonproliferation and national security technologies are often developed in classified environments because they require information about the production and signatures of weapons of mass destruction and their related delivery systems, and because many of the technologies could be rendered impotent if details of their operations were revealed. Nevertheless, to make effective use of developments in the overall scientific and technical community, personnel from the NN Tech Base must maintain contact with the broader scientific community and be active members of their professions: attending national meetings, presenting papers, and discussing their work with colleagues. This is especially true because new ideas often develop at the boundaries between traditional research disciplines.

Clearly, such professional interactions cannot involve classified technologies. However, there is often considerable overlap with the unclassified science base (e.g. the radiation detectors used in unclassified nuclear and high energy physics experiments as well as in uranium and plutonium tracking devices). It is often the application of a given technology or the relationship to an end-user that is classified, not the underlying science. When merited, NN-20 funding can and should support unclassified project work. Professional interchanges and contacts allow scientists and engineers within the DOE national laboratories to stay apprised of the progress of other groups and of the general state-of-the-art in technical areas. Such experiences allow NN Tech Base scientists and engineers to support NN-20 more skillfully and to call upon outside researchers and organizations when needed.

For all these reasons, additional effort should be focused on increasing contact between scientists and engineers of the NN Tech Base and the larger scientific community through mutual seminars, conferences and exchange of scientists, within the limits necessary to protect national security.

The DOE national laboratories are acutely aware of the need to maintain the highly trained and scientifically capable staffs of the NN Tech Base and other tech bases that serve other national needs. As funding at the DOE national laboratories has become less flexible, traditional sources of support for NN Tech Base have been impacted. In response, DOE laboratory administrators have maintained staff and expertise by offering other agencies their services through Work For Others (WFO) funding. While this is beneficial in many ways, as it allows expertise at the DOE national laboratories to be brought to bear on a wide array of national problems, both international and domestic, WFO should not be relied upon to sustain the specialized skills related to nonproliferation and national security that are essential to the NN Tech Base. DOE must remain a strong supporter.

7: The NN-20 R&D Portfolio

In this section we discuss the NN-20 R&D portfolio, its relevance to nonproliferation and national security needs, and its ability to meet NN-20's and DOE's responsibilities. The R&D portfolio is best understood in terms of its four program areas: (1) Nuclear Explosion Monitoring, (2) Proliferation Detection, (3) Proliferation Deterrence, and (4) Chemical and Biological Nonproliferation. The FY 2000 budget for the four program areas and their respective sub-areas is shown in Table 1 at the end of this section.

Nuclear Explosion Monitoring

The Nuclear Explosion Monitoring program area supports strategic U.S. national security objectives. The goal of the NN-20 nuclear explosion monitoring R&D effort is to provide the capability of detecting a nuclear explosion, determining the location and yield of the explosion, characterizing the device, and identifying the responsible party. After nuclear explosion monitoring technologies and systems are developed by NN-20, they are turned over to other U.S. Government agencies for deployment and operation. These technical systems are the *primary* means available to the Unites States to know when and where a state, or possibly a sub-state group, has detonated a nuclear device, whether it be underground, underwater, in the atmosphere, or in space. National security objectives require that the technologies be effective whether a nuclear explosion is declared or conducted evasively.

The Nuclear Explosion Monitoring program area also supports verification of international treaties: the 1963 Limited Test Ban Treaty (LTBT), the 1974 Threshold Test Ban Treaty (TTBT), the 1976 Peaceful Nuclear Explosions Treaty (PNET), and the 1996 Comprehensive Test Ban Treaty (CTBT), which has not been ratified by the U.S.

A nuclear explosion is an event with signatures that do not resemble those of other human activities or naturally occurring phenomena, except possibly at very low yield. The signals available from a nuclear explosion for collection and analysis are well understood. Signal strengths depend upon the yield of the explosion and the medium in which the explosion occurs. As yields decrease to low levels, discrimination (distinguishing a nuclear explosion from a non-nuclear event) becomes more difficult.

The question the United States must answer when making decisions about nuclear explosion monitoring and the verifiability of international nuclear testing treaties is: What is the *lowest yield* the U.S. needs to be able to detect and identify? The answer to that question is ultimately a national security policy judgment based on many factors: an understanding of the technical utility of testing devices with very low yields to a potential proliferator or a party that already has nuclear weapons, the military and political significance of such tests, and the chances of evading detection.

The end of the Cold War brought about a change in the emphasis of U.S. nuclear explosion monitoring. Previously the greatest attention was paid to monitoring nuclear explosions at declared nuclear test sites; in the post-Cold War era the greatest emphasis is on prevention of nuclear proliferation. For nuclear explosion monitoring the change requires global coverage, with particular emphasis on certain regions of the world and on evasively conducted nuclear tests.

Nuclear Explosion Monitoring is the oldest and best-known of the program areas in the NN-20 R&D portfolio. The program is organized into two sub-areas: Ground-Based Systems and Satellite-Based Systems.

Ground-Based Systems

Ground-based nuclear explosion monitoring systems are designed to detect signals generated by explosions in the earth, underwater or in the atmosphere as well as radionuclides generated by a nuclear explosion.

Seismic

NN-20's investments in recent years in seismic detection and analysis systems for underground nuclear explosion monitoring have supported: (i) detailed modeling of the propagation characteristics of regional geological structures in the earth's crust and the propagation of various types of seismic waves (called "phases") through these regional geologies, and (ii) advanced and automated signal processing systems. The first leverages the large international seismology scientific community that collectively operates a global network of instruments and exchanges data openly on naturally occurring seismic events (earthquakes, large to very small). The second leverages the ongoing revolution in computer and signal processing capabilities.

Major improvements have been steadily made over the last several decades in seismic detection technology for nuclear explosion monitoring, due in large part to NN-20 funding. The prospects for continued advances in capabilities are high. It is appropriate that seismic technology is continuing to receive the largest share of the budget for the Ground-Based Systems sub-area of the NN-20 R&D portfolio.

Radionuclide

Radionuclide detection and analysis is the second largest sub-area of NN-20's R&D investments in ground-based nuclear explosion monitoring technology. This sector, which also has a long history, traditionally dealt only with the detection of fallout (radioactive particulate matter) from nuclear explosions on the earth's surface or in the atmosphere—the "smoking gun" of a nuclear event. NN-20 R&D support in recent years has led to dramatic improvements in fallout detector capability (higher sensitivity, autonomous operation for a month or more, and self-reporting of data and system status). NN-20 funding in recent years has led to an entirely new class of radionuclide detectors. These latter systems detect four distinct radioactive isotopes of the inert gas xenon after cryogenic separation from atmospheric samples and by such means can discriminate between radio-xenon from nuclear explosions and that from nuclear reactors. All nuclear explosions release radio-xenon: it readily escapes into the atmosphere from nuclear explosions conducted on the earth's surface or in the atmosphere. Underground nuclear explosions may be also be detectable by radio-xenon means if the explosions are set off in media with fissures and other escape paths.

The NN-20 sponsored particulate detection system has already been commercialized, and the radio-xenon system is in the process of commercialization. NN-20's investments in radionuclide detection technologies have advanced U.S. capabilities substantially.

Hydroacoustic

Hydroacoustic detection systems make use of sensors that remotely detect underwater explosions (nuclear or conventional) by identifying the characteristic underwater acoustic disturbances that propagate outward from an explosion. Only a relative few sites are needed to monitor vast oceanic regions because low frequency sound readily travels long distances in the ocean sound channel. Hydroacoustic signals can be detected in-situ by underwater microphones (hydrophones), or on land by placing special purpose seismic detectors on small islands (where available). In the latter case, the underwater acoustic disturbances "shake" the island and generate seismic signals that are readily detectable. (Volcanic islands reaching up from the deep ocean are ideal.) Modest investments in developing hydroacoustic technology are important because the technology closes what otherwise would be a loophole, given that most of the earth's surface is water.

Hydroacoustic nuclear explosion monitoring technology leverages an existing vast body of sensors, propagation models, and expertise coming from submarine detection experience, oceanographic research, and commercial computing and signal processing capabilities. NN-20 investments in this sub-area are appropriate in scope and funding.

Infrasound

Infrasound explosion detection systems pick up acoustic signals in the atmosphere at frequencies far below the audible range. At such frequencies attenuation is so low that acoustic signals from a surface or low-altitude atmospheric nuclear explosion can be detected at intercontinental distances. The basic technology of infrasound is relatively inexpensive (microphones with high sensitivity at frequencies of 0.1-20 hertz and signal processors less complicated than the ordinary laptop computer). Infrasound mainly serves as a backup to radionuclide and space-based systems (discussed next), but because the technology is inexpensive and can be exported without technology transfer concerns, infrasound merits the limited investment NN-20 is making in this sub-area.

Satellite-Based Systems

Satellite-based sensors for detecting nuclear explosions on the earth's surface, in the atmosphere and above the atmosphere have long been established elements of U.S. national technical means (NTM). In the earliest days (1960s) dedicated satellites were used. For over three decades now, nuclear detonation detection system (NDS) packages have been flown piggy-back on satellites serving other missions. This occurred first on the early-warning Defense Support Program (DSP) satellites and later on the satellites of the Global Positioning System (GPS).

NN-20 has the prime responsibility for sustaining and advancing the entire suite of technologies that can be used for detecting nuclear explosions from space. Existing sensors include optical radiometers (bhangmeters) that detect the characteristic optical flash the comes from a nuclear explosion in the atmosphere up to medium altitudes; x-ray detectors and radio-frequency electromagnetic pulse (EMP) sensors for high attitude nuclear explosions; and neutron and gamma ray detectors for explosions above the sensible atmosphere.

Each new generation of DSP or GPS satellites brings changes in subsystem interfaces, data telemetry formats, and power and weight restrictions on payloads. The changes require NN-20 to go through a complete redesign of the NDS package, including demonstration and validation. Typically, DOE also takes advantage of these opportunities to introduce upgrades to sensors and sometimes add new sensors, enhance on-board processing and memory, and add other improvements to meet end-user needs. This responsibility is a major one and NN-20's record of accomplishment is outstanding. NDS packages are usually designed for a five-year lifetime, but typically continue to perform well beyond that, usually until the satellite is shut down. The unique knowledge and expertise that underpins the spaced-based nuclear explosion detection technology is a core component of the NN Tech Base discussed in the previous section.

Some of the recent R&D initiatives for improved satellite-based nuclear detection systems were motivated in part by the prospects for a CTBT. However, all of these space-based systems have always been and will continue to be part of U.S. NTM. Data collected from these systems are not shared internationally. The next round of NDS improvements that is slated for deployment represent significant improvements in sensitivity and localization and will provide valuable information to the U.S., independent of the CTBT.

Proliferation Detection

Proliferation Detection is the second largest program area of the NN-20 R&D portfolio. It is devoted to the identification of signatures of nuclear proliferation prior to a nuclear explosion and to sensors to detect such signatures remotely with instruments on satellites, airborne platforms, or possibly ground-based. The desire for such a capability has existed as long as nuclear weapons have existed, but only in the last decade or so have opportunities become available to pursue a significant R&D program. Several of the technologies being pursued by NN-20 in this program area may also be useful for detecting signatures of chemical and biological weapons proliferation.

The Proliferation Detection program area is divided into two broad sub-areas: Physical Detection and Effluent Detection. The first encompasses, in principle, all passive and active means (optical, infrared, radar, radio-frequency, etc.) that might be used to obtain information about a building, nuclear reactor, facility, neighborhood of a facility, piece of equipment, etc., indicative of a nuclear weapons program. The second sub-area encompasses those technologies that are particularly suited to detection and identification of gases and particulates that might be released from a nuclear-related facility on a continuous or intermittent basis, e.g., chemical releases from a putative plutonium reprocessing plant, or from a uranium enrichment facility. Both cooperative and non-cooperative scenarios are considered in each of the sub-areas.

Although the potential scope of this program area is vast, the funding limitations and the technological challenges of proliferation detection are such that NN-20 can support only a limited set of projects. Three of the technology development projects in this program area are large, multi-year, multi-laboratory efforts: Multispectral Thermal Imager (MTI), Hyperspectral Infrared Imaging Spectrometer (HIRIS), and Chemical Analysis by Laser Interrogation of Proliferation Effluents (CALIOPE). The first of these belongs to the Physical Detection sub-area, and the last two to the Effluent Detection sub-area. All three projects push the technological envelope and should be viewed as high-risk but potentially high-payoff investments. Such investments are necessary if the U.S. is to improve its nonproliferation capabilities. The challenge for NN-20 is to ensure that the technologies are of high quality and, if successful, will contribute to achieving national security objectives.

Physical Detection

The principal project of the physical detection program sub-area is the Multispectral Thermal Imager. Other projects in this sub-area are smaller, different in character, and have distinct proliferation detection applications.

Multispectral Thermal Imager

The Multispectral Thermal Imager (MTI) project is an integrated research satellite-sensor project that was started in late 1993 and is scheduled to be launched in early 2000 by the United States Air Force (USAF) under its competitive Air Force Space Test Program (free to DOE). The passive sensor has 15 spectral bands distributed over the wavelength interval 0.45 - 10.7 µm. Ground resolution varies with wave-band, ranging from 5 m at the shortest wavelengths to 20 m at the longest. MTI is designed for high absolute radiometric accuracy, rather than only measuring temperature differences. High accuracy absolute temperature measurements from space have not previously been feasible; this project represents a significant technical advance.

MTI is designed to operate for three years in orbit (at least through 2003), during which time vast amounts of data will be gathered. Much of it will be shared with members of the MTI Users Group, which includes individuals from DOE, other federal agencies, industry and the academic community. MTI is the largest project ever mounted by NN-20 or its predecessor organizations and has gone through numerous technical reviews and milestone evaluations.

MTI is a grand experiment designed to determine, through careful and systematic study, what can be observed from space that is applicable to the proliferation detection mission using a state-of-the-art, well-calibrated multispectral sensor. MTI is not a prototype instrument on a path to an end-user. MTI will undoubtedly also provide valuable information to other missions. The next research stage after MTI will depend on the quality and utility of the data it produces and the joint interests of NN-20 and its many partners in the project. It is too early now to judge the ultimate utility to the nonproliferation mission of space-based, high radiometric accuracy, multispectral thermal imagers.

Other Projects

The Physical Detection sub-area contains a number of other projects, smaller in funding than MTI, but no less important. The main ones are: synthetic aperture radar (SAR) algorithm and processing development, radio-frequency (RF) sensing and processing, and remote ultra-low-light imaging (RULLI) technology. SAR is a well established multi-purpose technology and has been an outstanding NN-20 investment for many years: the potential for further progress remains high. The RF technology and processing project is low risk and aimed at special purpose applications. RULLI is an original contribution developed under NN-20 sponsorship and has moved from the high-risk to the moderate-risk category.

Effluent Detection

Projects in this sub-area are focused on detection and identification of effluents indicative of nuclear proliferation activities. Success depends on a comprehensive knowledge of potential effluents, their behavior in the environment, and ability to detect and identify chemical species of concern. The technology may also support detection of chemical and biological weapons proliferation, or their use.

Hyperspectral Infrared Imaging Spectrometer

The Hyperspectral Infrared Imaging Spectrometer (HIRIS) is a passive infrared sensor operating in the 8-13 µm infrared region with vastly more bands than MTI (hence hyperspectral). The HIRIS instrument lacks the very high absolute radiometric accuracy of MTI but has greater spatial and spectral resolution. Note, however, the primary reason for the greater spatial resolution is that HIRIS is airborne rather than satellite-based. The narrow width of the individual bands of the HIRIS instrument combined, with its large number of bands, makes the discrimination of vast numbers of chemical species possible, providing the signal-to-noise ratio is adequate. The intended targets of HIRIS are effluent emissions characteristic of nuclear proliferation activities, e.g., releases from a plutonium reprocessing facility.

The basic nature of the HIRIS instrumentation and its planned applications mandates a much greater data processing capability than is required for the MTI system. Consequently, data processing and algorithm development are major components of the HIRIS project.

HIRIS, like MTI, is a large experiment centered around a state-of-the-art sensor that, beginning in a year's time, is scheduled to take large amounts of field data under a variety of conditions. HIRIS also has many interagency partners and potentially many applications. Proof-of-principle and test flights took place in 1998 and 1999, with real-world data collection scheduled for 2000-2002 and project completion in 2003. HIRIS is no less a grand experiment than MTI, except that it enjoys the relative simplicity of being airborne, which allows evolutionary development in contrast to the unforgiving character of space-based systems.

Lidar Systems

In 1993, NN-20 initiated a multi-laboratory program comprised of a suite of active lidar (laser radar) remote sensing instruments under the collective title Chemical Analysis by Laser Interrogation of Proliferation Effluents (CALIOPE). Since that time the technical content of the program has evolved and significant advances have been made in understanding and improving the technology. Annual field trials have been held at a calibrated effluent release facility at the Nevada Test Site since 1994 at increasing ranges, up to 20 km in some cases. The program is now focused on two projects: (1) an ultraviolet, laser-induced fluorescence (UV-LIF) instrument for detecting particulates on the ground; and (2) a differential absorption lidar (DIAL) infrared instrument to detect gaseous effluents. Active systems have specific advantages over passive systems, such as greater sensitivity in general, but they are more complex, require more power, and are intrusive.

The technical basis of the UV-LIF molecular identification is electronic excitation by an incident UV photon of the proper frequency and then subsequent detection of a photon emitted by the molecule as it decays from the excited state (fluoresces). By tuning the incident UV radiation over a range of frequencies and measuring the frequencies of the fluorescent returns, one can identify molecules of interest and discriminate against backgrounds.

The DIAL system works by tuning across a range of frequencies that cover the spectral features of molecules of interest. By comparing on- and off-resonance return strengths, a high selectivity for individual chemical species is possible.

The UV-LIF sensor is scheduled to be mounted on a high-altitude Altus UAV (unmanned airborne vehicle) owned by DOE. Engineering flights are scheduled for late 2000 and full-system experimental flights are scheduled to start in late 2001. Depending on results and the potential for enhancing proliferation detection capabilities, the project is likely to evolve into a combined active UV-LIF/passive IR system. The basic idea of the combined system would be that the passive IR system would be used to do a wide area search to identify local regions of interest by means of thermal characteristics. The lidar would then be used to look for chemical species indicative of specific effluents in the local regions (small search area). The Defense Threat Reduction Agency (DTRA) is interested in this project because of its potential for chemical and biological agent identification in DoD missions.

The DIAL system is also scheduled for significant development and ground trials over the next two years. The goal is an engineering prototype suitable for basing on an airborne platform. A combined active DIAL/passive IR prototype system by 2003 is envisioned as a joint DOE-DoD effort. The logic of using a combined passive-active system here is the same as for the UV-LIF/passive IR system.

The next few years will be important in demonstrating the field performance of these active lidar systems and their potential for detecting effluents characteristic of proliferation. Maximum stand-off distances, minimum sensitivities, probabilities of detection, and false-alarm rates are all of interest. It not possible at this time to predict the ultimate capabilities and utility of this technology.

Signatures of Proliferation

There is currently no project in the NN-20 portfolio explicitly directed to advancing current understanding of the signatures of nuclear proliferation. NN-20 has sponsored work on signatures in the past. NN-20 should have ongoing work in signature analysis and confirmation to refine current understandings of the robustness and strengths of signatures, possible backgrounds, and to prioritize those that appear to be the most promising. Without such a program there is no meaningful way to determine when a proliferation detection sensor technology, no matter how much it has advanced the start-of-the art, has reached the point at which meaningful operational system studies can be undertaken.

Proliferation Deterrence

The Proliferation Deterrence program of the NN-20 R&D portfolio has a history reaching back to the early days of Los Alamos. The content and emphasis of the program area has evolved greatly over the many decades of its existence. Proliferation Deterrence is the "clean-up" hitter of the NN-20 R&D portfolio and fulfills many critically important national needs. It can respond on short time-scales, when events dictate, and it has enduring responsibilities.

The primary sub-areas of Proliferation Deterrence are: Treaties and Agreements, Nuclear Material Tracking and Control, Off-Site Analysis, On-Site Analysis, and Support for Law Enforcement.

Treaties and Agreements

Treaties and agreements for which this program sub-area has provided technical support in the past include: Intermediate Nuclear Forces Treaty (INF), Chemical Weapons Convention (CWC), START I and II, International Safeguards, and the Highly Enriched Uranium (HEU) Purchase Agreement. Possible future treaties and agreements that will benefit from the knowledge and technical expertise of the members of this part of the NN Tech Base include START III**,** the Fissile Material Cutoff Treaty, the Mayak Fissile Material Storage Facility Transparency Agreement, and the Plutonium Production Reactor Agreement.

Members of this program sub-area work closely with members of the Office of Arms Control and Nonproliferation (NN-40) and provide support for the DTRA under terms of an integrated DoD/DOE plan. The work relates to DoD responsibilities in the areas of Cooperative Threat Reduction and On-Site Inspection.

Monitoring challenges that must be solved include detecting the presence or absence of fissile material by non-invasive means, the isotopic ratios and ages of plutonium samples, and devising systems with robust information barriers that will perform a gamma-ray spectral analysis of a warhead to verify that it is or is not a nuclear weapon without revealing classified design information.

Nuclear Material Tracking and Control

This program sub-area is primarily concerned with developing advanced gamma-ray and neutron detector systems for detecting, localizing, and characterizing the presence or transit of nuclear material. The technical contributions of this program sub-area are also centrally important to the task of enhancing the tools available for managing real nuclear terrorist incidents or hoaxes.

Recent creative contribution**s** of this program sub-area include compact, field-portable gamma-ray spectrometers based on new types of scintillation crystals for identifying the unique radiological characteristics of fissile materials and nuclear weapons, and novel radiation "litmus" paper that changes color when exposed to a threshold radiation dose.

Off-Site Analysis

The fundamental difference between technologies belonging to this sub-area and those discussed above in the Proliferation Detection program area is that here it is assumed that a physical sample (solid, liquid, or gas) is available and can be transported to a state-of-the-art laboratory for analysis. The physical, chemical, biological and interdisciplinary resources of the entire DOE laboratory complex can thus be exploited.

Eleven DOE laboratories are the primary participants, and collectively they bring a vast array of analytical tools and systems to bear. Most recently, ultra-sensitive detection and analysis technologies that enable information to be extracted from microsamples have made striking advances. The primary emphasis is nuclear proliferation, but the research and technology also contributes to chemical agent identification. The potential for further progress in this sub-area is great, with contributions coming from DOE laboratories, industry, and universities.

On-Site Analysis

This program sub-area is similar to Off-Site Analysis except that here the assumption is that samples are available but, for whatever reasons, cannot be transported from the collection site to a specialized laboratory. The sub-area supports on-site treaty inspectors, transparency exercises, counter-nuclear smuggling, and specialized intelligence and law enforcement needs.

Similar to its off-site counterpart, this sub-area is multidisciplinary and multi-laboratory. Compact gas chromatographs, ultra-sensitive effluent ”sniffers,” miniature mass spectrometers, and a host of other chemical and physical detection and sensing technologies are being developed as field-portable devices. There is a synergy between the miniaturization that is taking place with respect to laboratory systems off-site and what is needed for on-site analysis systems.

Support for Law Enforcement

This sub-area is the newest component of the Proliferation Deterrence program area. It is based on a Memorandum of Understanding between DOE and the Department of Justice/FBI Laboratory. The MOU allows for broad areas of cooperation, extending well beyond domestic nuclear terrorism. The off- and on-site detection and analysis capabilities discussed above have numerous applications to law enforcement, as do numerous other technical capabilities resident in the DOE laboratory system.

Chemical and Biological Nonproliferation

Chemical and Biological Nonproliferation is the newest program area of the NN-20 portfolio. It was created in FY1997 in response to Presidential and Congressional direction. The program is devoted to developing, demonstrating, and delivering technologies and systems that will lead to major improvements in the U.S. capability to prepare for and respond to domestic chemical and biological attacks. It engages the expertise in chemical and biological sciences resident in the DOE laboratories, and is part of the overall U.S. response to the chemical and biological weapons threat. The same DOE science and technology base that supports this program area is being tapped by other federal agencies under “Work For Others” agreements.

A five-year Strategic Plan (FY00-FY04) for the Chemical and Biological Nonproliferation program area was developed in 1999. It specifies specific goals and milestones and divides the program area into two major sub-areas: (1) Technology Development and (2) System Integration/Domestic Demonstration and Application Program. The program has included end-users in its planning process since its conception.

Technology Development

The Technology Development program sub-area is comprised of four project areas: Biological Foundations, Chemical and Biological Detection, Modeling and Predictions, and Decontamination and Restoration.

Biological Foundations

The goal of this project area is, “To provide essential biological information for medical countermeasures.” Work is organized under seven technical areas: signature development and validation, engineered organism detection, background characterization, genomic sequencing, structure/function determination, epidemiology tools, and infomatics. Spin-offs to the DoD’s Biological Weapons Threat Reduction effort and to the disease monitoring efforts of the public health community are likely.

Chemical and Biological Detection

The goal of this project area is, “To provide early warning, identify people to treat, and identify contaminated areas with high sensitivity and low false alarm rates." To fulfill the goals of this project area, a suite of detectors and sensors are being planned for use by first responders (law enforcement officials, fire fighters, and emergency medical service personnel). Several classes of urban targets characterized by large concentrations of people are being considered, e.g., subways, airports, train stations, and large sporting events. Detection technology for first responders must be simple, portable, low-cost, and provide a fast response—a challenging set of requirements. Additional technologies are being developed for expert forensic analysis of samples brought to a laboratory setting. These systems need be highly sensitive, represent or exceed state-of-the-art capabilities, and be able to detect threatening agents in the presence of contaminants—the usual state of samples taken in real-world environments. Advanced forensic capability is needed to distinguish between natural and unnatural outbreaks of diseases and to provide positive identification of the agent or agents involved. DNA information can sometimes be used to identify particular strains that, in the case of biological agents, may reveal the geographic location of the source.

Modeling and Predictions

The goal of this project area is “To develop predictive modeling tools for urban environments inside and outside of facilities.” Major tasks include: developing a suite of validated multi-scale transport and fate models for chemical and biological agent releases; applying modeling capabilities to simulation case studies; integrating the modeling capabilities in the National Atmospheric Release Advisory Center (NARAC); and exercising the models in the PROTECT (subways, airports, and train stations) and BASIS (Salt Lake City Olympics) demonstration projects.

Decontamination and Restoration

The goal of this project area is “To quickly restore civilian facilities.” Restoration is important because untreated facilities may remain contaminated for decades. Decontamination and restoration present many challenges, some technical and others practical. Among these are the development of decontaminant formulations that can destroy or detoxify hazardous chemicals or biological pathogens while remaining harmless to people and property. A formulation that is effective for all chemical and biological agents would be particularly useful. Application methods for interior and exterior environments have to be identified. In addition, reliable sampling methods need to be developed to monitor the decontamination process as it proceeds and to measure the extent of residual contamination. The variety of surface materials present in the urban environment make this a difficult problem. Although decontamination and restoration may not be considered as glamorous as work at the fundamental science level, they are important to achieving the goals of the Chemical and Biological Nonproliferation program.

System Analysis and Integration

In addition to technology development, DOE has accepted the challenge of working with state and local safety and law enforcement officials to develop an integrated approach to domestic chemical and biological weapons terrorism. This requires practice and experience at the operational level. This area of work consists of two parts: (1) an umbrella project called PROTECT, a systems approach to the interior infrastructure problem; and (2) BASIS, a special events protection demonstration scheduled for the 2002 Salt Lake City Olympics.

PROTECT currently includes plans for aerosol dispersal studies after hours in the Washington DC Metro System, air flow and detector architecture studies at the International Terminal of San Francisco Airport, and studies at Boston South Station. BASIS will emphasize multi-site communications and sensor information exchange.

The NN-20 Chemical and Biological Nonproliferation program is off to an excellent start on an important, timely, and challenging mission. Its Strategic Plan provides a coherent framework for program administration, identifying needs, setting priorities, and assessing progress. The program brings NN-20 into contact with a unique and diverse set of end-users—first responders at the state and local levels—and at the same time the program must interface with multiple federal agencies. The potential contributions of the NN-20 Chemical and Biological Nonproliferation program to national needs are great. As program funding grows, as it must to meet its assigned goals, it is important that funding for the other program areas of the NN-20 R&D portfolio is not sacrificed. The threat of nuclear proliferation is increasing and effective nuclear nonproliferation technologies need continued support.

Summary

Each of the four program areas of the NN-20 R&D portfolio addresses U.S. nonproliferation and national security objectives in a manner consistent with Executive and Congressional mandates. The technical quality of the work in each program area is high. There is a clear correspondence between the four NN-20 R&D program areas and three “elements” of the *DOE National Security R&D Portfolio*: NN-20’s Nuclear Explosion Monitoring program area maps onto *Monitoring Nuclear Treaties and Agreements*; the Proliferation Detection program area maps onto *Detecting Proliferation*; the Chemical and Biological Nonproliferation program area maps onto *Countering WMD Terrorism*; and the Proliferation Deterrence program area maps in part onto *Monitoring Nuclear Treaties and Agreements* and mostly onto *Countering WMD Terrorism*. The need for continuing R&D in all four program areas remains high because the threat posed by proliferation of weapons of mass destruction shows no sign of decreasing.

The Nuclear Explosion Monitoring program area has work remaining to bring technologies and data analysis systems already at an advanced level to the point where they can be transitioned to an end-user. In addition, there is a need for continued fundamental work to enhance nuclear explosion monitoring capabilities for low yields, especially work related to nuclear tests conducted evasively. The Proliferation Detection program area has three large, multi-year remote-sensing projects (MTI, HIRIS, and CALIOPE) that will be reaching experimental maturity and collecting significant data in field tests in three or less years. For each, a major decision will need to be made in a timely manner to determine if the potential utility of the technology merits going to the next stage of prototype development. The Proliferation Deterrence program area will continue to be essential to support treaties and agreements that require verification of a wide range of activities including: dismantlement of nuclear warheads, fissile material production cutoffs, tracking and control of nuclear materials, and safe and secure disposition of highly enriched uranium and weapons-grade plutonium. The Chemical and Biological Nonproliferation program area is just completing the first year of its five-year strategic plan.

NN-20 should proactively define and communicate a five-year plan for its R&D portfolio that balances end-user needs and opportunities for new research initiatives. Because of pressing end-user needs, a large fraction of the current NN-20 R&D portfolio is focussed on short-term technology development. In order to stay abreast of technological advances and to insure that opportunities for new capabilities are not missed, a larger share of the NN-20 R&D portfolio should go to new research areas than is currently the case. Unless the pattern of end-users need changes, this will require additional funding beyond the new advanced concepts funding discussed earlier in this report.

Table 1: FY 2000 NN-20 Budget

Nuclear Explosion Monitoring			**$73M**
Ground-Based Systems (R&D)		$23M	
	Seismic		
	Radionuclide		
	Hydroacoustic		
	Infrasound		
Satellite-Based Systems (R&D)		$13M	
Satellite-Based Systems (Production Related)		$37M	
Proliferation Detection			**$66M**
Physical Detection		$25M	
	Multispectral Thermal Imaging		
	Synthetic Aperture Radar		
	RF Sensors		
	Low Light & Laser Assisted Imaging		
Effluent Detection		$41M	
	Hyperspectral Imaging Spectrometer		
	Lidar Systems (CALIOPE)		
Proliferation Deterrence			**$35M**
Treaties and Agreements		$ 4M	
Nuclear Material Tracking and Control		$ 9M	
Off-Site Analysis		$ 9M	
On-Site Analysis		$ 8M	
Support to Law Enforcement		$ 5M	
Chemical/Biological Nonproliferation			**$40M**
Biological Foundations		$11M	
Chemical and Biological Detection		$13M	
Modeling and Prediction		$ 5M	
Decontamination and Restoration		$ 2M	
Systems Analysis and Integration		$ 9M	
Small Business Innovation Research			**$ 5M**
TOTAL			**$219M**